1945

# Occupational chemical hazards in industries of Louisville and Jefferson County.

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# OCCUPATIONAL CHEMICAL HAZARDS IN INDUSTRIES OF LOUISVILLE AND JEFFERSON COUNTY

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Department of Chemistry

By

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TITLE OF THESIS: Occupational Chemical Hazards in Industries of Louisville and Jefferson County

APPROVED BY READING COMMITTEE COMPOSED OF THE FOLLOWING MEMBERS:

Guy Stevenson

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______________________

NAME OF DIRECTOR: C. C. Vernon

## PREFACE

The facts and conclusions presented in the following pages are the results of figures gathered during two and one half years of work as an Industrial Hygiene Engineer for the Louisville and Jefferson County Health Department. The factual information was acquired from many sources including extensive reading to which reference is made of the more recent publications in the bibliography and also from correspondence and discussions with authorities in various fields. Much data was gained from "in-service training" received at the United States Public Health Service; Bureau of Industrial Hygiene, Bethesda, Maryland; University of Michigan; National Conference of Governmental Industrial Hygienists' Meeting, St. Louis, Missouri; and from the Bureaus of Industrial Hygiene of the States of Michigan, Indiana and Illinois.

ACKNOWLEDGEMENT

Without the full cooperation so freely given by all the industries and unions of Jefferson County and the assistance from the staff of the Industrial Hygiene Bureaus of the Louisville-Jefferson County and Kentucky State Health Department this paper would not have been possible.

The author wishes to thank all those persons who have made this paper possible and it is hoped that Industrial Hygiene will contribute more to the health of industrial workers in the future.

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# OCCUPATIONAL CHEMICAL HAZARDS IN INDUSTRIES OF LOUISVILLE AND JEFFERSON COUNTY

## INDUSTRIAL STATUS OF LOUISVILLE

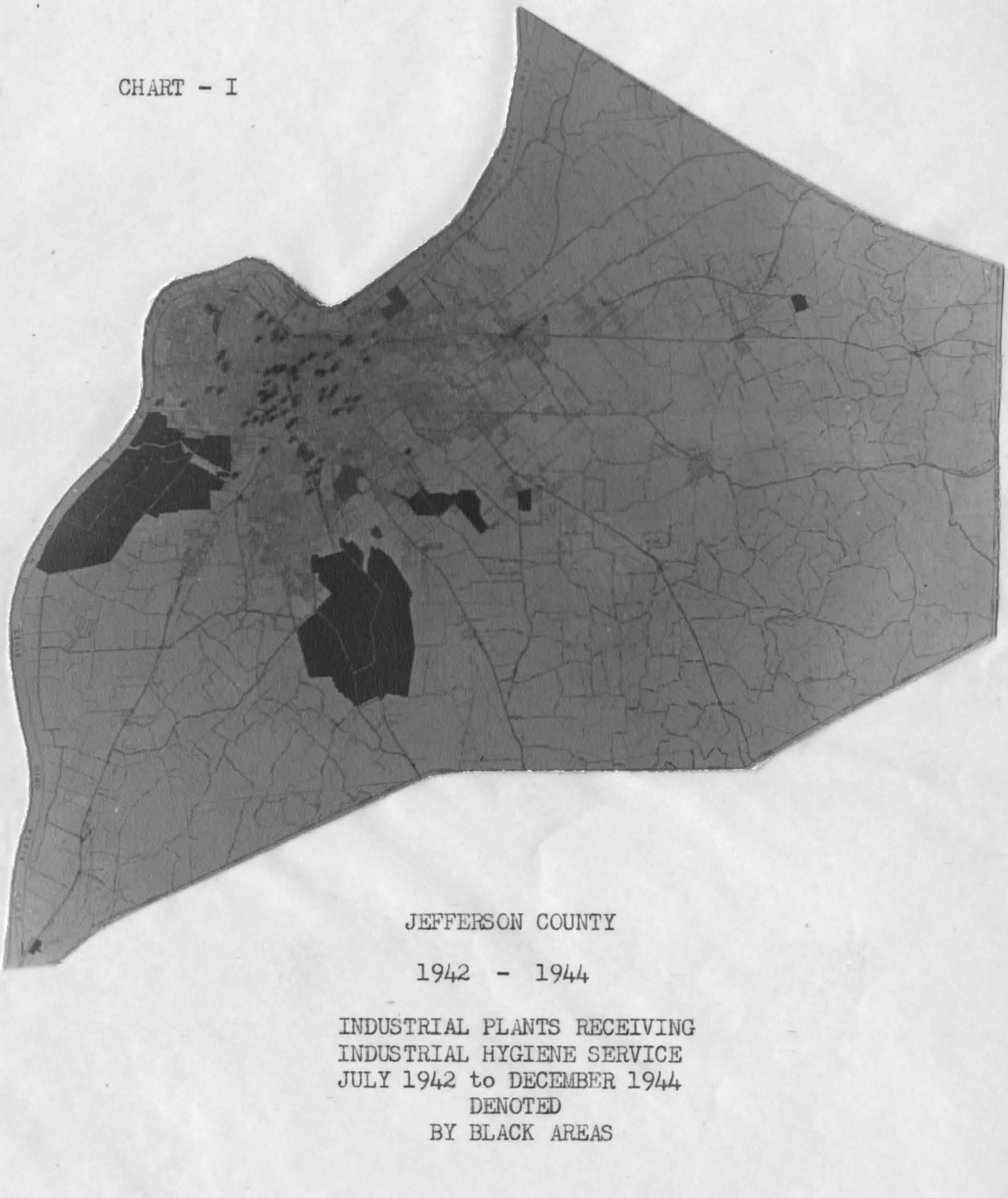
The State of Kentucky ranks 26th among the forty-eight states as to the number of gainfully employed workers in its manufacturing industries, (1940 census). Using the number of industrial workers as a gauge, there are five major industrial centers in the state (36). Louisville ranks first with 31,114 workers employed by industry in 1940 and the following cities are listed in decreasing order of their importance as industrial centers: Covington has 3,822 workers, Ashland has 3,597, Owensboro has 2,837 and Paducah has 2,501. The majority of the manufacturing establishments of Jefferson County are located in or near Louisville proper.

The industrial plants of Jefferson County Kentucky that receives the services of the Bureau of Industrial Hygiene of the Louisville and Jefferson County Health Department are indicated on CHART I, page 3, and are listed individually in Table II, page 3A- . Chart I and Table II summarize the Industrial Hygiene work performed by the Industrial Hygiene Engineer of the Louisville-Jefferson County Health Department for the manufacturing industries of Jefferson County during the period of July 1942 to December 1944. The black areas on the map represent industrial plants or groups of plants that have improved their health standards through the evaluation surveys of the Bureau of Industrial Hygiene.

CHART III (36) is a census of manufacturers (1939) giving the number of wage earners engaged in manufacturing by states. Kentucky ranked 29th in 1939 as to the number of wage earners in factories. In 1940, the last date that a complete census was taken, Kentucky had climbed to 26th place in this group.

CHART IV shows the market value of Louisville's manufacturers. These statistical figures indicate the importance of this industrial area in the production of war materials. (24).

CHART - I



JEFFERSON COUNTY

1942 - 1944

INDUSTRIAL PLANTS RECEIVING
INDUSTRIAL HYGIENE SERVICE
JULY 1942 to DECEMBER 1944
DENOTED
BY BLACK AREAS

12-10-44 M. B. Lewman

TABLE II

| Name | Industrial Visits | Samples Analyzed | Atmospheric Measurements Made |
|---|---|---|---|
| Adams, W. T. Broom Company | 3 | 6 | 6 |
| Adler Manufacturing Company | 4 | 8 | 6 |
| Agate Sewer Pipe Company | 5 | 4 | - |
| American Air Filter Company | 7 | 9 | 9 |
| American Brass & Aluminum Works | 2 | - | - |
| American Elevator & Machine Company | 5 | 4 | - |
| American Radiator & Standard Sanitary Corp. | 3 | 8 | 8 |
| American Woolen Company | 3 | - | - |
| Bade Cummins | 2 | 3 | - |
| Battery Manufacturing Company | 2 | 6 | 5 |
| Bomar Manufacturing Company | 1 | - | - |
| Bond Brothers | 1 | - | - |
| Bradas & Gheens | 3 | - | - |
| Brown & Williamson Tobacco Corporation | 2 | 8 | 8 |
| Cherokee Sanitary Milk Company | 1 | - | - |
| James Clark Electric Company | 5 | 5 | 4 |
| Cochran Foil Company | 3 | 4 | 4 |
| Cohart Refractories Company | 24 | 105 | 91 |
| Columbia Mantel Company | 1 | 8 | 8 |
| C. Lee Cook Manufacturing Company | 2 | 5 | 4 |
| Courier-Journal Job Printing Company | 1 | - | - |
| Courier-Journal & Louisville Times | 1 | - | - |
| Curtiss-Wright Corporation | 4 | 1 | - |
| C. T. Dearing Printing Company | 2 | 6 | 5 |
| Devoe-Reynolds Company | 2 | 6 | 6 |
| The Dickson Company | 4 | 7 | 7 |
| Drummond Manufacturing Company, Inc. | 2 | 6 | 6 |
| E. I. du Pont de Nemours & Company, Inc. | 4 | 9 | 8 |
| Durkee Famous Foods | 1 | - | - |
| Falls City Brewing Company | 1 | - | - |
| Geo. G. Fetter Company | 2 | - | - |
| Ford, Bacon & Davis | 1 | - | - |
| Frankfort Distilleries | 3 | 1 | - |
| Gamble Brothers | 2 | 3 | 5 |
| General Box Company | 2 | 8 | 8 |
| General Shoe Lace Company | 2 | 4 | - |
| Gibbs-Inman Company | 3 | 4 | 7 |
| Girdler Corporation | | | |
| Thermex, Votator & Gas Processes | 1 | - | - |
| Tube Turns (2 plants) | 5 | 9 | 11 |

TABLE II (CONT'D.)

| Name | Industrial Visits | Samples Analyzed | Atmospheric Measurements Made |
|---|---|---|---|
| B. F. Goodrich (2 plants) | 7 | 14 | 14 |
| Hart Manufacturing Company | 4 | 12 | 10 |
| The Herald Printing Company | 3 | 7 | 9 |
| Hillerich & Bradsby Company | 1 | 6 | 10 |
| Hoffman Gas & Electric Company | 4 | 8 | 7 |
| I.C.R.R. Roundhouse | 2 | 3 | - |
| Jones Dabney Company | 2 | 6 | 5 |
| Kentucky Color & Chemical Company | 5 | 12 | 15 |
| Kentucky Concrete Pipe Company | 2 | - | - |
| Kentucky Foundry Company | 3 | 6 | 6 |
| Kentucky Ignition Company | 1 | - | - |
| Kentucky Lithographing Company | 1 | 2 | - |
| Kentucky Macaroni Company | 3 | - | - |
| Kentucky Manufacturing Company | 2 | 6 | 10 |
| Kingham Trailer Company | 2 | 5 | 7 |
| Liberty Engineering & Manufacturing Co. | 2 | 2 | - |
| Logan Company | 2 | 3 | - |
| Louisville Bridge & Iron Company | 1 | 5 | - |
| Louisville Car Wheel & Railway Supply Co. | 3 | 12 | 12 |
| Louisville Chair & Furniture Company | 3 | 5 | 10 |
| Louisville Crushed Stone Company | 2 | 6 | 6 |
| Louisville Drying Machinery Company | 1 | 3 | - |
| Louisville Electric Mfg. Company | 2 | 2 | - |
| Louisville Electrotype Company | 2 | 4 | 6 |
| Louisville Fire Brick Company | 4 | 9 | 14 |
| Louisville Lamp Company | 2 | 3 | - |
| Louisville Refinery Company | 4 | 4 | - |
| Louisville Sewer System | 25 | 25 | 25 |
| L. & N. (South Louisville Yards) | 5 | 14 | 16 |
| Louisville Textile Company | 3 | 9 | 15 |
| Louisville Tool & Die Company | 2 | - | - |
| Mack Truck Company | 1 | 6 | 6 |
| Mengel Body Company | 6 | 11 | 15 |
| Mengel Company (Fibre Containers) | 2 | 4 | 4 |
| Mengel Box Company | 1 | - | - |
| Merrimac Battery Plate Company | 2 | 4 | 4 |
| Murphy Elevator Company, Inc. | 2 | 5 | 5 |
| National Carbide Corporation | 21 | 9 | 20 |
| National Youth Administration (Trng. Center) | 3 | 6 | 9 |
| Neighborhood House | 2 | 8 | 8 |

TABLE II (CONT'D.)

| Name | Industrial Visits | Samples Analyzed | Atmospheric Measurements Made |
|---|---|---|---|
| Palmer Asbestos & Rubber Corp. | 6 | 4 | - |
| J. V. Pilcher Mfg. Company | 5 | 12 | 15 |
| Porcelain Metals Corporation | 2 | 3 | - |
| Reynolds Metals Corp. (6 plants) | 35 | 42 | 35 |
| Reynolds Research Corporation | 4 | 6 | - |
| Robertson Company, Inc. | 3 | 10 | 6 |
| Rommel Construction Company | 3 | 6 | - |
| Schmutz Foundry | 5 | 12 | 11 |
| Schmutz Foundry & Machine Company | 2 | - | - |
| Schuler Axle Company | 2 | 3 | - |
| Joseph E. Seagram | 4 | - | - |
| Semple Manufacturing Company | 3 | 8 | 8 |
| Shannon Spring Bed Company | 1 | 4 | - |
| Spengrey Cap Corporation | 6 | 30 | 30 |
| Standard Gravure Corporation | 1 | - | - |
| Standard Printing Company | 2 | 4 | 3 |
| Stiglitz Furnace & Foundry Company | 1 | - | - |
| Struck Construction Company | 4 | 15 | - |
| Tobacco By-Products & Chemical Corp. | 3 | 8 | 8 |
| Turner Day & Woolworth Handle Co. | 3 | 8 | 18 |
| Henry Vogt Machine Company | 7 | 10 | 15 |
| Vultee Aircraft, Inc. | 5 | 1 | - |
| Westinghouse Naval Gun Mounting Plant | 5 | 7 | 7 |
| Western Electric Company | 3 | - | - |

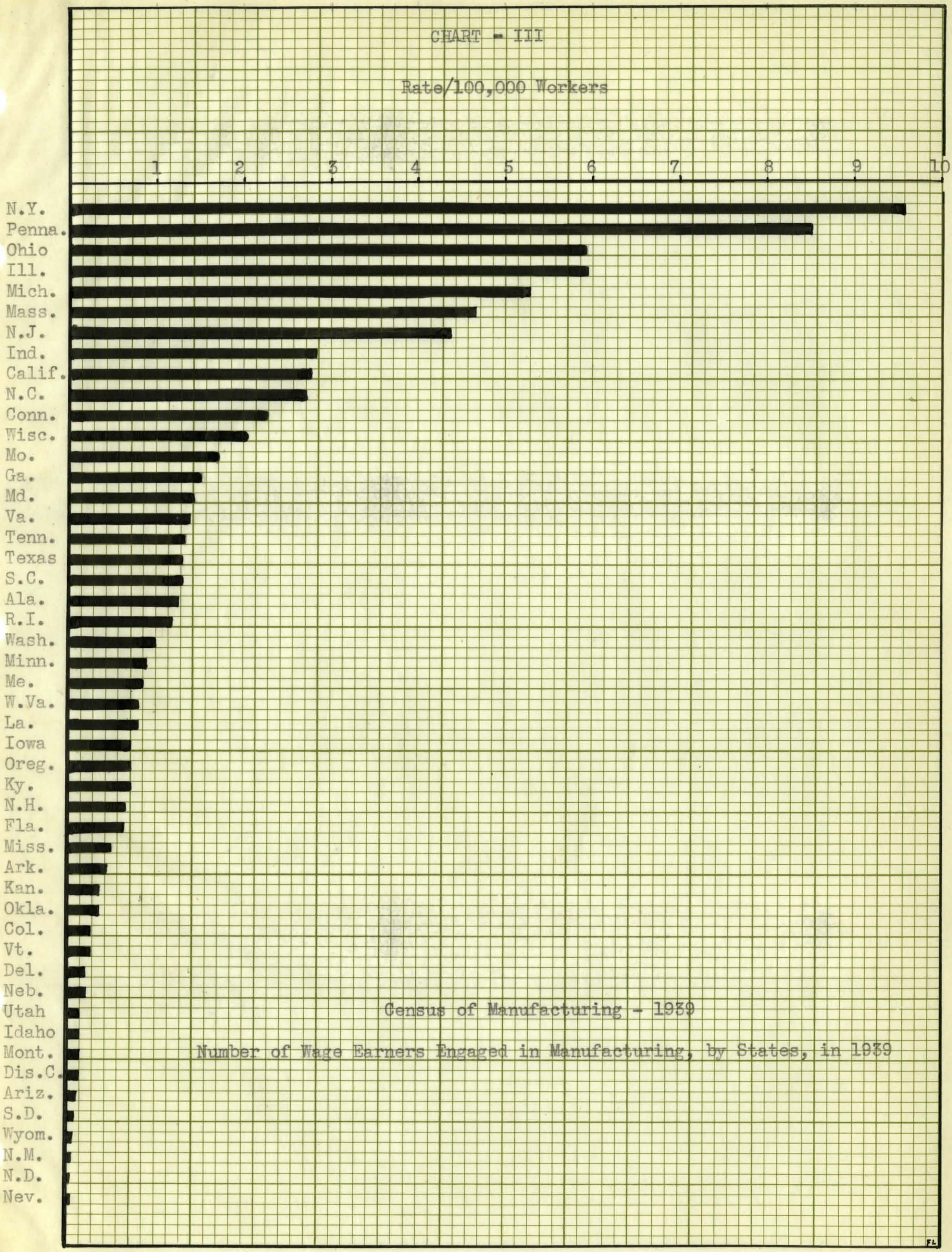


CHART - III
Rate/100,000 Workers
1
2
3
4
5
6
7
8
9
10
N.Y.
Penna.
Ohio
Ill.
Mich.
Mass.
N.J.
Ind.
Calif.
N.C.
Conn.
Wisc.
Mo.
Ga.
Md.
Va.
Tenn.
Texas
S.C.
Ala.
R.I.
Wash.
Minn.
Me.
W.Va.
La.
Iowa
Oreg.
Ky.
N.H.
Fla.
Miss.
Ark.
Kan.
Okla.
Col.
Vt.
Del.
Neb.
Utah
Idaho
Mont.
Dis.C.
Ariz.
S.D.
Wyom.
N.M.
N.D.
Nev.
Census of Manufacturing - 1939
Number of Wage Earners Engaged in Manufacturing, by States, in 1939

CHART IV

VALUE OF INDUSTRIAL PRODUCTION FOR LOUISVILLE

| Year | Value |
|---|---|
| 1933 | $ 198,985,000 |
| 1937 | 309,228,000 |
| 1939 | 323,000,000 |
| 1940 | 320,000,000 |
| 1942 | 460,950,000 |
| 1944 (estimate) | 1,050,000,000 |

War Plant Investment (Federal Funds) as of July 1944, Louisville ranked 12th with $309,595,000. War contracts for the period from June 1940 through October 1944 totaled $1,310,248,000.

HISTORICAL SKETCH OF THE DEVELOPMENT OF LOUISVILLE

Historically there is a reason for the centralization of industries in this area. Records show that the first white people of this section settled on Corn Island, now submerged because of the Hydro-Electric Dam. This island was opposite what is now Twelfth Street. These early settlers were hunters and trappers and this particular location was of advantage because of its proximity to a mode of transportation, the Ohio River, and being surrounded by water it offered a certain amount of security against surprise attacks by the neighboring Indians. Directly below Corn Island was the Falls of the Ohio, caused by a series of geological formations of rock strata. These Falls are the only ones in the Ohio River from its source in Pennsylvania to its mouth, where it empties into the Mississippi at Cairo, Illinois. This distance of 981 miles of navigable water, except for the Falls, was of great importance to the early settlers of this state in moving their cargo from place to place. The Falls, a natural barrier to the movement of cargo from the point of procurement to a potential market, proved to be a focal point for a settlement. Although this was not the first permanent settlement in Kentucky it had an early beginning as an industrial and commercial center.

Before the Louisville and Portland Canal was constructed in 1826-1831, the settlement aided river transportation by furnishing river pilots to guide boats and barges over the rapids when the water level was sufficiently, high. During the low stages of the water, which was usual at all times except the period of spring rains, boats were unloaded and the cargo was taken by land around the Falls and reloaded onto the river craft which had passed over the falls or onto other barges or boats. The moving of cargo from a point above to a point below the rapids gave employment to many men. Often the goods were displayed and offered for sale on the river-front markets. It was in this way that Louisville early became a well recognized river port and trading center.

About the year 1783 Evan Williams opened a distillery at Fifth and Water Street. This was the first manufacturing plant established in the town. From this pioneer beginning Louisville has grown from a small trading post to a modern industrial center, ranking 18th in the United States as to value of industrial products in 1942. Not only is it centrally located from a geographical standpoint, but it is also within 105 miles of the center of population of the country (1940). This central location along with other factors, such as low wage scales, good rail and river transportation, a promising airborne freight center, favorable tax rates for new industries, as well as an abundance of electrical power at a rate comparing well with other industrial centers, indicates a greater manufacturing center in the future. The last four years has seen Louisville's industrial rank, not only in the field of materials of war, but in the fields of much needed civilian goods, climb to an important position.

## STATUS OF INDUSTRIAL WORKERS AND WORKING CONDITIONS

In Louisville, as in many other towns and cities of this country which had their beginning as much as 200 years back, may be found many old, well established industries. Others have mushroomed in the last five years. Many of the more firmly established industries are still under the guidance of their founder. As a result, varied working conditions are found in these plants. These conditions vary, not only the physical aspects of the machinery and the building itself, but also in the attitude of the management toward the workers. Recently unions, or organized labor, have had their influences upon the working conditions within the industrial plants as well as a control over the worker's outside activities. It would be difficult to draw a conclusion as to who was the first to champion improved working conditions in the interest of the worker. It may have been the management itself or, it may have been a group outside of management who found that a worker who is given good working conditions, a reasonable amount of security and comfortable living quarters is an asset to the industry as well as a better citizen. Be that as it may, a phase of technological development known as Industrial Hygiene has further improved the relationship between labor and management as well as improved working conditions from the standpoint of health hazards.

## INDUSTRIAL HYGIENE

Poisons were known to exist and have been used from time immemorial, but poisoning due to occupational exposure was not clearly defined in the minds of ancient and medieval men. Hippocrates (460-357 B.C.) described lead poisoning as an occupational disease in the smelting of metals. In the seventeenth century Ramizzine (1635-1711), regarded as the father of Industrial Hygiene, wrote De Morbis Artificum (Diseases of Tradesmen). Russia and England were the first countries to recognize that the pursuit of certain trades held inherent hazards for the worker due to chemical exposure. It was not until about 1910 that any attention was given to the study of occupational hazards of a chemical nature in this country. It was about this time that Alice Hamilton (13) started a study of this kind. In 1912 the Esch Law was passed. This law prevented the use of white phosphorus in matches by placing a prohibitive tax on its use. This substance is the cause of the horrible phossy jaw of match workers. It was in 1915 that the United States Public Health Service and the Bureau of Mines conducted a lengthy study of health hazards, mostly silica dust, among the hard rock miners of Joplin, Missouri.

## AIMS AND PURPOSES

Briefly, Industrial Hygiene is an applied science which pertains to the improvement and protection of the health of working people. It includes the application of Public Health Standards to the industrial worker in relation to his occupational environment. It is obvious that some of the problems of Industrial Hygiene arise from the nature of the industry itself. Since the industrial worker spends 25 percent of his days on his job, the materials he handles, the work he does and the conditions under which he works has a marked influence on his physical and mental well being. During the last 25 years numerous studies have indicated that illness among workers in industrial plants is often associated with or due to the conditions under which they have to work. The health of the industrial worker is, as a general rule, below the standard of that of persons engaged in non-industrial work. It has been found that disabling illness is 16 percent higher among unskilled labor and 40 percent higher among skilled laborers than in the so-called non-industrial group. The death rate among skilled laborers is estimated to be 24 percent higher, among semi-skilled labor 50 percent higher and among unskilled labor 116 percent higher than in the non-industrial group. In 1938 the occupational death toll of industry was 19,000 persons. These deaths may be sub-divided into accidental deaths and deaths resulting from occupational diseases. The latter is only a small percentage of the former, less than 10 percent, but both are astonishing facts. It is the purpose of the science of Industrial Hygiene to study the cause and effect of occupational hazards and reduce them to a minimum.

INDUSTRIAL HEALTH HAZARDS

There are approximately 2500 occupations in which there is a potential exposure to chemicals in concentrations which may reach toxic or lethal limits. There are some 900 chemicals in common use in industry today.

Harmful substances are not limited to a small number of industries. Lead is a hazard in over 150 industries; arsenic is a hazard in at least 50 industries and benzene is a hazard in about 50 industries. As a result of research in an effort to open new fields and to supplement shortages of natural products to meet the present demands for such products, new compounds are being added to this list. The number of occupational disease hazards encountered in any one industry may be small but there are many industries in which there are a large number of industrial disease hazards. The one industry of tanning has as many as 42 occupational disease exposures, many of which are of a chemical nature. Among these we may mention hydrogen sulfide, hydrogen cyanide, arsenic, mercury and chromium compounds.

The industrial chemical hazards that have been found in the industrial establishments in Louisville and Jefferson County would represent an average cross section of exposure that would be found in other production centers of the United States. The most hazardous and most prevalent health hazards will be considered. Their chemical and physical properties will be stated and field data that has been gathered on certain serious exposures will be outlined.

## TOXIC THRESHOLD LIMITS

Man, or the worker as we shall consider him in this discussion, is a wonderful biological mechanism, the inner workings of which we know too little. No two individuals react alike to a cause, be it mental, physical or moral.

Although under a true democracy we have equal rights we are not in truth created equal physically nor do we develop individually to a standard pattern. It is for this reason that man's response to chemical exposures which he may encounter in industry is so varied.

In the past a great deal of effort has been expended in the study of the materials found on or in the earth. Studies and research that give us a wealth of information as to the physical and chemical properties of these substances have been made. From these studies and their results many chemicals have found commercial use in the industrial world.

Although volumes of statistics have been gathered over a number of years that prove conclusively that a majority of occupations have a detrimental effect upon the health and life span of its workers. Not until recently has anything been done to correct such hazards. Alice Hamilton (13) was the first crusader in this work. Though she was a single individual carrying the torch in a new field of preventive industrial health her efforts left a mark; her influence and teachings have been felt by many who have followed in her footsteps.

In the past decade or so a concentrated effort has been made to understand the effects of these substances upon the human body and the physical harm that results from the unsafe handling of these substances. It seems that in time of war, where many inexperienced workers are thrown in contact with such chemicals, a renewed effort is made by a small group of doctors and scientists to measure, evaluate and suggest control measures in the handling and processing of substances that may have an adverse physiological effect on the human body.

Today one finds scattered throughout the country many individuals, groups and organizations located in universities, institutions and government agencies working to correlate facts that will give us a better understanding of the effects upon the human system of the various substances that have or will find use in industrial plants. The Air Foundation of the Mellons Institute, a research group backed by a number of industrialists, and the National Conference of Industrial Hygienists are two of the larger groups working in this science.

The phase of this study which is of greatest interest to the industrialist and to the workers has to do with the maximum amount of various contaminants the average person can tolerate during an exposure of a working day without impairing the normal healthy functions of the human body. Much has been accomplished and work is still in progress in establishing these maximum concentrations or as they are now referred to "the permissible threshold limits". Such data requires a full knowledge of all immediate and remote physiological effects of gas, vapor, ray, or particulate matter to which the individual is in contact and some method of determining quantitatively the limits of these effects in terms of the concentrations to which one is subjected. Due to the complexity and nature of this experimental work there are some variations in the results obtained. Moreover, standards now in effect are subject to revision as further work is done in this field. Just recently the standards or threshold limits set for a familiar solvent, carbon tetrachloride, has been revised downward as the result of observation in the industrial field of mild symptoms of their toxic effects on numerous individuals working in atmosphere where the concentration of carbon tetrachloride was maintained below the old established threshold of 100 PPM. This standard is still under consideration with the concentration tentatively set at 50 PPM.

It is now the concensus of opinion that such figures as have been established as the toxic threshold limits should be used solely as "bench marks" and the industrial hygienist should draw on his back-log of experience in determining whether any one particular exposure is a health hazard to the individual worker. It is the hope of many toxicologists in the field that a scale of tolerance be worked out for each material used in industry so that its hazards to the worker's health may be evaluated as its concentration changes during a working day. For many gases and some organic vapors the physiological action has been studied so that the extent of their effects on the health of an individual can be charted as the concentration of the substance in the atmosphere varies. "Noxious Gases" by Henderson and Haggard (15) gives us much information on this subject.

TABLE V

MAXIMUM ALLOWABLE CONCENTRATIONS OF ATMOSPHERIC CONTAMINANTS (29) (35)

| Group I | Gases and Vapors | PPM* |
|---|---|---|
| Acetone | | 1000 |
| Acrolein | | 1 |
| Aliphatic acetates | | 500 |
| Ammonia | | 100 |
| Benzene (benzol) | | 75 |
| Bromine | | 1 |
| Carbon dioxide | | 5000 |
| Carbon disulfide | | 20 |
| Carbon monoxide | | 100 |
| Carbon tetrachloride | | 50 |
| Chlorine | | 1 |
| Ether (diethyl ether) | | 500 |
| Ethylene dichloride | | 100 |
| Formaldehyde | | 10 |
| Hydrogen chloride | | 10 |
| Hydrogen cyanide | | 20 |
| Hydrogen fluoride | | 3 |
| Hydrogen sulfide | | 20 |
| Methyl alcohol (methanol) | | 100 |
| Nitrogen oxides | | 39 |
| Perchlorethylene | | 100 |
| Petroleum vapors | | 500 |
| Phosgene | | 1 |
| Sulfur dioxide | | 10 |
| Toluene (toluol) | | 200 |
| Trichlorethylene | | 100 |
| Turpentine | | 200 |
| Xylene (xylol) | | 100 |
| **Group II** | **Dusts** | **MPPCF**** |
| Asbestos | | 5 |
| Nuisance (no free $SiO_2$) | | 50 |
| Silica | | 5 |
| **Group III** | **Computed as:** | **$Mg/10M^3$***** |
| Cadmium | Cd | 1 |
| Chromic acid | $CrO_3$ | 1 |
| Fluorides | F | 25 |
| Iron Oxide fume | $Fe_2O_3$ | 150 |
| Lead | Pb | 1.5 |
| Magnesium oxide fume | MgO | 150 |
| Manganese | Mn | 60 |
| Mercury | Hg | 1 |
| Zinc oxide fume | ZnO | 150 |

* Parts per million parts of air by volume.
** Million particles per cubic foot of air, standard lightfield count.
*** Milligrans per ten cubic meters of air.

## TOXIC AND HAZARDOUS MATERIALS

### INORGANIC

The metallic chemical hazards of industry are usually found when a metal which is toxic to the human body is dispersed in the air in the form of dust or fume, or as a vapor in the case of mercury and telurium. In this dispersed form the metal finds ready entrance into the body through the air breathed, or in some instances through breaks in the skin, ultimately reaching the blood stream. To effect the human body the metallic substance must be in solution in the body fluid during the period of transmission to the body cells. As even the most insoluble substance is relatively more soluble the more surface it presents to its solvent, the more finely divided a material is that enters the body the more readily it will become compatable with the body fluids. Therefore, in the industrial process in which a relatively toxic substance is handled it is of importance that the finely dispersed material be properly controlled so that the worker is not subjected to amounts above the permissible threshold limit.

### LEAD

Metallic lead has been mined, smelted and many uses made of it for well over 2000 years. Plumbison, a disease due to lead in the blood stream, has been recognized since Biblical times. Due to its physical properties, softness and low melting point lead is widely used today. Like any other toxic substance, proper handling will nulify its hazardous nature. Because of its low melting point, in processes that do not thermostatically control the heat of the molten lead pot, the possibility exists of an atmosphere heavily contaminated with lead fumes. Lead poisoning from metallic lead, its alloys and inorganic compounds, is rated as ten times more liable to occur from breathing lead fumes or dust than from swallowing it (13). According to the present theory on lead absorption in the body the liver removes lead from the blood stream. This is done more readily if it finds its way to the liver through the alimentary tract than if the lead enters the body by inhalation through the lungs and thus into the blood. In the latter instance it is pumped all over the body and its toxic effect is felt more readily than it would be otherwise. Tetraethyl lead, an organic lead compound widely used in gasoline blending, may be absorbed through the skin. Lead absorbed by the liver finds its way into the bony structure where it is stored. It is believed that lead is toxic only when present in the systemic circulation. When a saturation point is reached and the bones can no longer store lead or if a diet high in calcium content is adhered to, the body will gradually de-lead itself through the kidneys. There is danger in this process of too rapid removal of lead from the bones to the blood, thereby raising the lead level to the toxic point. Symptoms of lead poisoning such as would come from external exposure to lead may result.

Extended field sampling has shown that the minimum amount of lead usually present in the atmosphere of industrial establishments is 0.10 miligrams per 10 cubic meters and 0.13 miligrams per 10 cubic meters in auto shops. At congested street intersections the concentration may reach 0.09 miligrams per 10 cubic meters. The generally accepted standard for safe working conditions is 1.5 miligrams per 10 cubic meters (29).

ZINC

Solid metallic zinc is not a poison in the true sense of the word. Zinc dust or the fumes from zinc and its alloys, in the form of zinc oxide have long been recognized as the cause of Metal Fume Fever, often referred to as brass founders ague, metal shakes, oxide chills, brass chills, glavo and zinc oxide fever (7). Today it is known that the oxide of most heavy metals, when inhaled in large amounts, will be absorbed to produce toxic proteins or albuminate of the metal. These albuminates will produce severe transient febule reaction resembling protein shock in nature and symtomatology and is commonly referred to as metal fume fever (8). Welders of galvanized iron when not protected by exhaust ventilation or the proper type respirator, or both, will suffer from metal fume fever which usually lasts from two to twenty-four hours. The first symptoms are a dry throat, metallic taste followed by chill and fever and a white cell count increase. There has been no reported therapy to eleviate this condition and as far as is known no permanent damage results from such attacks (8).

## WELDING

In iron and steel construction during this war welding has supplemented riveting. Much welding today is employed in shipbuilding and a high percentage of this is done in confined places down in the ships' holds where natural ventilation is poor and artificial ventilation must be resorted to. Flash burns from the ultra-violet light of the arc is a recognized hazard in electro-welding. The fumes resulting from iron and steel welding is a possible health hazard and at present an extensive survey is being conducted by the United States Maritime Commission and the Industrial Hygiene Division of the United States Public Health Service to study the effects of welding fumes on welders in the shipyards of the United States.

Ninety percent of the welding rods used today are coated to increase the efficiency of the welding operation. During this operation the coating and some of the metal rod burns. The composition of the coating (Chart VII, page 19) will give an indication as to what the gases and the fumes involved will consist of.

The percent composition of the fumes given off when welding mild steel with any of the E6000 rods, when welding galvanized iron and when using the stainless steel rod is tabulated below (33):

TABLE VI

COMPOSITION OF WELDING FUMES (33)

| | Stainless Steel | E6000 on Mild Steel | E6000 on Galvanized Steel |
|---|---|---|---|
| $Fe_2O_3$ - $TiO_2$ | 16.1% ($Fe_2O_3$) | 60-70% | 30% |
| $SiO_2$ | 5.8% | 10-30% | 4% |
| $MnO_2$ | | 2-12% | 1% |
| F (as compounds) | 17.6% | | |
| $Cr_2O_3$ | 8.3% | | |
| NiO | 2.3% | | |
| CaO | 9.7% | | |
| $MnO_2$ | 2.8% | | |
| ZnO | | | 65% |

TABLE VII

ANALYSIS OF COATINGS IN MILD STEEL AND STAINLESS

STEEL WELDING ELECTRODES (8)

American Welding Society Types

| Electrode Coatings | E 6010 | E 6011 | E 6012 E 6013* | E 6020 E 6030 | Stainless |
|---|---|---|---|---|---|
| $H_2O$ | Under 10% | Under 10% | Under 10% | Under 10% | Under 10% |
| Sodium silicate | 30-40% | 25-35% | 10-20% | 10-20% | 15-20% |
| Cellulose | 20-30% | 20-30% | 3-10% | Under 5% | |
| $MgSiO_3$ | 10-25% | 15-30% | 10-20% | 5-20% | Under 10% |
| $TiO_2$ | 10-20% | 10-35% | 30-50% | Under 6% | Under 10% |
| Ferro Mn | 10-20% | 5-10% | Under 10% | 5-20% | Under 10% |
| MgO | | 5-10% | Under 5% | Under 5% | |
| $ZrO_2$ | | Under 5% | Under 5% | | |
| $Al_2O_3$ (clay) | | 5-7% | 5-11% | Under 10% | |
| $SiO_2$ | | | 15-20% | 10-30% | Under 15% |
| Feldspar | | | 10-20% | | Under 10% |
| Mica | | | | 10-20% | |
| $CaCO_3$ | | | | Under 10% | 20-30% |
| Iron Oxide | | | | 15-30% | |
| $MnO_2$ | | | | 10-25% | |
| $CaF_2$ | | | | | 20-30% |
| Mn | | | | | Under 10% |
| Mo | | | | | Under 5% |
| Cr | | | | | Under 5% |

* Note: E 6013 same as E 6012 except cellulose may be up to 25%.

It is a simple matter to demonstrate the presence of iron oxide in the welding fumes from iron and steel. This component is measured by impinging upon filter paper the oxide from a measured quantity of air. This spot test gives a fairly reliable index as to the adequacy of ventilation. The maximum limit has been set at 15 miligrams per cubic meter. It has been shown that minute quantities of $NO_2$ are given off, the coated rod giving off less than the uncoated rod. This gas is a lung irritant and the group that is studying welding fumes states that this gas is the hazardous element in these fumes. As amounts of $NO_2$ found in welding fumes are below the toxic limit, the method of analysis is not sensitive enough or else some other component not thus far considered is the cause of welders suffering discomforts from their occupation.

Nitrogen dioxide in the form of $N_2O_4$ is a colorless liquid which boils at 26° C. This liquid changes molecular structure and color with increase in temperature; at 15° C. it is orange, at 20° C. the liquid, a mixture of $N_2O_4$ and $NO_2$, begins to boil and the vapors are reddish brown, at 40° C. the vapor becomes dark chocolate brown and at 140° C. it is black. At body temperature or 40° C. the ratio of the two molecular forms is 30% $NO_2$ and 70% $N_2O_4$ and in this proportion the gases act upon the respiratory tract. In the presence of water and oxygen the following reactions take place:

$$N_2O_4 + H_2O \text{ --- } HNO_3 + HNO_2$$

$$3NO_2 + H_2O \text{ --- } 2HNO_3 + NO$$

and

$$4NO + 2O_2 + 2H_2O \text{ --- } 4HNO_3$$

The nitrous acid reacts with the alkali in the tissues of the respiratory tract causing endemia of the lungs and irritation. The nitrate formed has no physiological significance, but sodium nitrite is a systemic poison. Each milligram of nitrogen dioxide acting upon the respiratory tract forms 0.75 milligrams of sodium nitrite. The inhalation of the threshold limit of 39 PPM of nitrogen dioxide will result in the absorption of approximately 20 milligrams of sodium nitrite (assuming effective pulmonary ventilation of 6 liters with complete absorption). The physiological effect is the same as if the sodium nitrite is taken orally. The arteries are dilated, the blood pressure falls and vertigo and headache follows. Nitrous fume poisoning is the most insidious of all those caused by irritant gases, toxic exposures cause endemia of the lungs and the victim actually drowns by the volume of fluid poured out into the lungs.

PHYSIOLOGICAL RESPONSE TO THE VARIOUS CONCENTRATIONS OF NITROUS FUMES

| | PPM |
|---|---|
| Least amount causing irritation to the throat | 62 |
| Maximum permissible (threshold limit) | 39 |
| Dangerous for even short exposure | 117 - 154 |
| Fatal | 240 - 775 |

## MERCURY

Mercury is a protoplasmic poison and one of the few metals that will prove toxic to a human being either by entrance through the skin or by inhaling the vapors. As a protoplasmic poison it stops the metabolism of all living matter. Mercury being a liquid with high vapor pressure evaporates readily at ordinary temperatures and will contaminate the air wherever it is exposed. The following table gives the vapor pressure and concentration in saturated air at each temperature. Actually these concentrations in the air are very seldom reached under normal conditions as they pre-suppose equilibrium between the mercury vapor in the air and the liquid metal. Only under quite unusual conditions is this state attained.

VAPOR CHARACTERISTICS OF MERCURY (15)

| Temperature (centigrade scale) | Vapor pressure of mercury | PPM |
|---|---|---|
| 20 | 0.0013 | 1.84 |
| 30 | .0029 | 4.10 |
| 40 | .0060 | 8.50 |
| 60 | .0300 | 42.50 |
| 100 | .2800 | 396.00 |
| 300 | 246.0000 | 348,000.00 |

The occupation that presented the greatest hazard of mercury poisoning was that of the hat furriers trade in which the rabbits fur, or felting, was treated with a mercury compound to stiffen and curl the hairs, a process called carroting. This particular operation has been abandoned because of the toxic reaction it produced upon the workers.

The generally accepted permissible threshold limit is between 0.1 and 0.2 mg. of mercury per cubic meter of air or 12 to 24 parts per million parts of air. A daily exposure above these amounts will produce systemic poisoning upon an individual.

It is the purpose of Industrial Hygiene not only to prevent possible acute or chronic poisoning due to improper handling of chemicals, but also to lower to a minimum any discomforts that might result from sub-toxic exposures to harmful chemicals. The effects of mercury is a good illustration. The sensitivity of the skin to mercury varies with the individual. In Louisville the exposure to mercury is probably greatest in the chemical or physical testing laboratories. There are individuals who are so allergic that an exposure of one hour to small amounts of mercury vapor that arise from what is spilt in the cracks of the floor and in the sink will cause a skin rash. In a case like this the concentration is so far below the threshold limit that the average person will suffer no discomfort from the vapors.

In chronic mercury poisoning the main symptoms are salivation, stomatitis, and nervous disturbances; however, the most striking symptom is the psychic disturbance, Erethismus mercurales, characterized by a peculiar form of excitement and timidity (15). The nervous system may be affected by the development of what is called mercural tremors.

PHOSPHORUS

The industrial hygiene hazard of phosphorus has been largely exterminated in this county since the federal government imposed a heavy tax on the use of white phosphorus in matches.

SUMMARY

The above statement covers such metals and their compounds as were prevalent industrial hazards in the industries of Louisville during the years from 1942 to 1944 inclusive. This is not a complete catalog of all metals and their compounds that may prove to be toxic to the human system under high atmospheric exposure. Manganese, radium and cadmium are some of those that do not find wide use in this area. It will be well to qualify this last statement for completeness of this report that radium is used industrially in this area in the form of paint for aircraft instrument dials, but due to the need for military security, the area in which this operation is performed is restricted to military personnel only. The control of the hazards of radium poisoning in these plants has been under the supervision of the Bureau of Industrial Hygiene of the United States Public Health Service. Although the hazards of handling this material are inherently insidious; experience in the results of improper handling of radium has taught industry that inadequate control measures are more expensive than compensation for workers that suffer from radium poisoning. This is a wasting disease that usually terminates in death after five to fifteen years of suffering.

GASES AND VAPORS

## HYDROGEN SULFIDE

Industrially, hydrogen sulfide is found prevalent in tanneries, fat rending plants and refineries in Louisville. High concentrations will cause immediate death due to systemic action. Hydrogen sulfide even in low concentration exerts a marked irritation upon the cornea of the eye. The surface epithelium is eroded, there is usually marked photophobia, and a feeling as if grains of sand were on the surface of the eye.

Irritation is produced both by abstraction of alkali from the cells and by the sodium sulfide formed which is caustic. In the blood stream sodium sulfide is hydrolized with the liberation of hydrogen sulfide. If the blood hemoglobin contains oxygen, the hydrogen sulfide is oxidized to the harmless sulfate and the blood count is proportionately reduced.

Asphyxia develops as a result of the paralysis of breathing induced by high concentrations (600 - 1500 PPM) of hydrogen sulfide. The heart, however, continues to beat for several minutes after respiration has ceased. If the subject can be induced to breathe by artificial means or if artificial respiration is maintained until the hydrogen sulfide in the blood is oxidized to the sulfate, normal respiration soon becomes re-established. However, exposure to an atmosphere containing over 1,800 PPM of hydrogen sulfide will cause almost immediate death (11).

Because of its characteristic odor and irritating effect there is some indication of the relative concentration of such a gas in the air. Yet in acute poisoning it is as toxic in effect as hydrogen cyanide. The maximum permissible concentration is 20 PPM and fatality results after 30 minutes exposures at 600 PPM.

AMMONIA GAS

From a toxicological standpoint the above gas is a volatile poison, having its own specific physiological action. The following gases act as asphyxiants or pulmonary irritants, the most common to the layman is ammonia gas. One will encounter ammonia gas from many sources as it is stored in the liquid form in steel cylinders, is extensively employed as a refrigerant, is produced in the manufacture of coal gas and the destructive distillation of bones. An aqueous solution of it in the form of ammonium hydroxide yields the gas on exposure to air.

Ammonia gas from any of these sources is irritating to the upper respiratory tract and any degree of exposure will effect respiration and the heart functions. From the industrial standpoint ammonia may cause acute poisoning due to mechanical failure of systems containing ammonia under pressure such as is found in refrigeration systems or ammonia storage cylinders.

The following table gives the physiological response to various concentrations of ammonia.

PHYSIOLOGICAL RESPONSE OF MAN TO AMMONIA GAS (15)

| | PPM |
|---|---|
| Least detectable odor | 53 |
| Least amount causing irritation of the throat | 408 |
| Least amount causing coughing | 1,720 |
| Maximum threshold limit | 85-100 |
| Maximum concentration allowable for short exposures | 300-500 |
| Rapidly fatal for short exposures | 5,000-10,000 |

Assuming all individuals equal in their reaction to ammonia gas, one can readily see by the above table that atmospheric concentrations five or six times the threshold limit may be safely endured for a short period of time. In all but a very few cases, such as processes that would use ammonia continuously, the latter tolerance limit could be applied. The usual industrial exposure to ammonia gas is of short duration, perhaps on an average approximately 5 or 10 minutes.

It is also of interest to note that the sense of smell is not a good index as to the extent of the physiological action of a gas or vapor upon the body. As is true of many substances, the concentration of ammonia that is least detectable is very near the value set as the maximum allowable limit for healthful working conditions. Because the sensitivity of the olfactory sense is deadened by continuous exposure to small concentrations of odoriferous gases it cannot be depended upon to evaluate exposures to these gases.

HYDROCHLORIC ACID (HYDROGEN CHLORIDE)

Hydrochloric Acid may be classed as a readily volatile acid to the extent that when it is heated the acid itself passes into the air. One of the most common industrial uses of this acid in Louisville, other than in some synthetic rubber plants and the powder plant, is as a pickling liquor for iron. In this process the iron is immersed in a cold or warm acid solution of varying concentrations, a copious evolution of hydrogen results, and each bubble escaping is coated with a film of acid that is carried into the air. The toxicity of the acid vapors is less than the anhydrous gas due to the fact that the moist gas has lost its dehydrating action.

PHYSIOLOGICAL RESPONSE TO VARIOUS CONCENTRATION OF HYDROCHLORIC ACID GAS (15)

| | PPM |
|---|---|
| Causes irritation of throat on short exposure | 35 |
| Maximum threshold limit | 10 |
| Maximum concentration allowable for 1 hour | 50-100 |
| Dangerous for even short exposures | 1,000-2,000 |

## SULFURIC ACID

Sulfuric acid is found as an atmospheric contaminate industrially in metal "pickling" and the charging of lead storage cells. Although it is more corrosive than hydrochloric acid, its dehydrating action is similar to the anhydrous HCl gas. Due to its high molecular weight as compared with HCl the toxic limit expressed in milligrams 1 liter of air is higher for $H_2SO_4$ than for HCl although expressed as PPM, they are about the same.

## FORMALDEHYDE

Formaldehyde is a colorless gas. Usually used in water solution in the manufacture of plastics and as a preservative, it finds commercial application in Louisville in the manufacture of a water-proof fiber container. One of the components in the water-proof plastic resin glue being formaldehyde solution.

The powerful irritating action of formaldehyde upon the mucous membrane of the nose and throat is due to its forming an irreversible combination with the protein of the surface cells and with living tissues it changes into formic acid and methyl alcohol. The latter has a marked toxic effect on the human system when absorbed in sufficient quantities.

PHYSIOLOGICAL RESPONSE OF FORMALDEHYDE (15)

| | PPM |
|---|---|
| Threshold limit | 20 |

SULFUR DIOXIDE

Sulfur dioxide is encountered from an industrial standpoint in manufactures that use sulfur bearing coal, coke or oils. In the burning or oxidation of these materials the sulfur combines with the oxygen of the air to form this colorless, irritating, irrespirable gas. There is very little danger from acute sulfur-dioxide poisoning as the fumes are so irritating that the victim is compelled to seek air at once.

Workers subjected to lower concentration, which would cause chronic poisoning, complain of headaches, anorexia, spasmodic coughing, bronchitis, gastro-intestinal disorders, conjunctivitis, lacrimation, and anemia. Although the workers acquire a toleration to these effects, exposure to concentrations above 10 PPM over a prolonged period of time will produce ulceration of the mucous membrane (26).

## CHLORINE

Chlorine is 20 times as toxic as hydrochloric acid and because of its low solubility its locus of action in the respiratory tract is much more extensive than is that of hydrochloric acid. The theory is that Cl abstracts hydrogen from the water present in the tissues and the librated nascent oxygen and the HCl formed causes oxidation and primary irritation to the tissues.

PHYSIOLOGICAL RESPONSE OF MAN TO CHLORINE (15)

| | PPM |
|---|---|
| Maximum threshold limit | 1.0 |
| Least detectable odor | 3.5 |
| Allowable for short exposure (up to 1 hour) | 4 |
| Dangerous for even short exposure | 40-60 |
| Fatal | 1000 |

## ACROLIN

Acrylic Aldehyde commonly occurs in industry when fats, oils, or glycerines are heated to high temperature. It is the main irritant in the exhaust of internal combustion engines, especially in diesel engines when there is incomplete oxidation of the lubricating oils.

PHYSIOLOGICAL RESPONSE OF MAN TO ACROLIN (15)

| | PPM |
|---|---|
| Least detectable and threshold limit | 1.0 |
| Intense irritation | 5.5 |
| Lethal in a short time | 10.0 and over |

CARBON MONOXIDE

Although rare in nature it is almost universally present wherever man lives and has fires.

| ILLUMINATING GAS | CARBON MONOXIDE |
|---|---|
| Coal gas | 4-6% |
| Water gas | 40% |

City gas containing from 6-30% carbon monoxide with sufficient air will burn to carbon dioxide and water, but even so if the blue flame is brought against a cold body such as a water pipe in a hot water heater, or a cooking utensil carbon monoxide may escape due to incomplete combustion or may be formed from other carbonacedus gases such as methane which is sometimes present in illuminating gas.

The smoke of a coal or wood fire contains various amounts of carbon monoxide depending upon how free the draft is. An improperly drafted coke fire produces an even larger amount of carbon monoxide.

Exhaust gas of internal combustion engines contain from 1-7% carbon monoxide. A rough estimate of the volume of carbon monoxide formed by an automobile is 1 cu. ft./min./horse power; sufficient to render a single car garage deadly within 5 minutes.

Carbon monoxide is not a cumulative poison, as is lead or silica dust, but after severe asphyxia followed by prolonged coma the victim generally dies within 36 hours without regaining consciousness. Carbon monoxide combines with the hemoglobin of the blood to the exclusion of oxygen. Its affinity for hemoglobin is 300 times greater than that of oxygen. This reaction is reversible and may be stated as:

$$HbO_2 + CO \rightleftharpoons HbCO + O_2$$

This reaction does not injure the red corpuscles and if the oxygen replaces the carbon monoxide before the victim is asphyxiated, recovery is rapid. Except for this one reaction this gas is physiologically inert and animals which have no hemoglobin are quite normal in 80% carbon monoxide and 20% oxygen. All of the toxic action of carbon monoxide is exercised through the anoxemia resulting from the conversion of oxyhemoglobin to carbon monoxide hemoglobin, and the resulting asphyxia. The elimination of carbon monoxide is the reverse of the absorption process, as the carbon monoxide is not oxidized to carbon dioxide, but must be replaced by oxygen, therefore inhalation of 5% carbon dioxide-oxygen mixture will hasten the recovery by effecting better ventilation through rapid and deeper breathing.

DUST

Dust may be defined as an aerosol of a particular type in which solid matter, or dust, is the dispersed phase and air is the continuous phase. Dusts other than that wind-blown from dry fields have been generated by mechanical friction and has come about through the development of civilization by man. In general, dust is from many types of material and only in a few isolated cases is it a single variety of matter. Dust is the greatest single industrial hazard. As most all dust enters the body by inhalation into the lung, it is the cause of many respiratory diseases, such as tuberculosis, pneumonia, chronic bronchitis and pleurisy. The inhalation of silica or asbestos dust in concentration above the permissible threshold limit over a period of years will cause a marked increase of fibrous or scar tissue resulting in the diseases called respectively silicosis and asbestosis. Exposure to metal-bearing dust such as lead, zinc and most heavy metals will cause systemic poisoning of industrial workers.

The human respiratory system is so constructed that particles larger than 10 microns (10 ) are not able to find their way into the lungs, where they may be absorbed into the circulatory system. Free silica dust reacts with the lung tissue resulting in progressive nodulation. Therefore from the industrial hazard aspect, dusts may be considered as particles or aggregates of particles suspended in the atmosphere ranging in size from 0.5 to 10 .

SILICA DUST

The most common dust hazards found in industries of Louisville (during 1942-44) was caused by siliceous dust, examples of which are, molding sand, diatomaceous earth and similar substances. One of the few occupational diseases for which workers are compensated by law in most every state is silicosis. Exposure to high concentrations of siliceous dust will cause this disease in young, inmature workers readily and the older workers in a matter of years. Due to its few outward symptoms, without periodic X-ray examinations of the chest this disease may reach advance stages before the worker is aware of it and in a short time becomes incapacitated. At the present time there are two mobile X-ray trailer units and two portable units in the state of Kentucky that spend a part of their time educating and X-raying industrial workers for tuberculosis and silicosis.

At present there are no manufacturers in the Louisville area in whose processes some form of siliceous dust is handled that protects their workers completely from hazardous concentration of this dust. Some have made marked advances in the last two years and are well on the way to complete control of this hazard. In this area siliceous dust is more prevalent in foundries than in most other types of industry and control of the exposure is financially impractical under present housing and methods of operations for a majority of the foundries, especially those that have been in operation for a quarter of a century or more.

The shakeout (the removal of casting from the molds and the core from the casting), and sand reconditioning are two operations in a foundry that will dispense large quantities of silica bearing dust into the workroom if they are not sufficiently protected by enclosures and exhaust ventilation.

Chest X-ray survey of large groups of foundry workers have shown that about 3% of the workers who have followed this trade five or more years had silicosis and 4.5% had fibrosis of the lung (28). This pulmonary bilateral nodular fibrosis progresses slowly and according to accepted theory today (23) the "free silica" dust has a physiochemical action on the lung tissues due to the formation of a silica hydrosol. The different siliceous dust may vary in their harmful effects in proportion to other substances present. This may explain the beneficial effects of the inhalation of small concentration of aluminum dust in the treatment or prevention (?) of pneumoconiosis (silicosis).

The time necessary for the development of a case of silicosis depends upon several factors; the higher the percentage of these factors, the more rapidly pneumoconiosis will occur:

1. The amount of free silica in the dust.
2. Concentration of particles below 10 microns in size in the air breathed.
3. Duration of exposure.

The first factor is determined by chemical and petrographic analysis of an atmospheric sample of the dust. It is common practice to use a "rafter" or settled dust sample for this analysis; this is not a true sample of the type and size of dust inhaled by the workers for numerous reasons, the most influential of which is the effect of particle size on the rate of settling of a dust particle. This is shown below, assuming the particle to be spherical in shape and of unit density and falling in still air:

TABLE VIII

THE SETTLING RATE OF DUST PARTICLES IN STILL AIR (10)

| Diameter of Particle | | Rate of Settling | |
|---|---|---|---|
| Cm | Microns ($\mu$) | Cm/sec. | Meters/hour |
| $10^{-2}$ | 100 | 30 | 1080 |
| $10^{-3}$ | 10 | 0.3 | 10.8 |
| $10^{-4}$ | 1 | 0.003 | 10.8 cm. |
| $10^{-5}$ | 0.1 | 0.00003 | 1.08 mm. |

With the slow rate of fall of particles 10 microns (10 $\mu$) or less in size the slightest air movement would continually change the composition of dust settling over a particular area and although it would have an equal effect on the air in the "breathing zone" of the worker the factor of time would give greater weight to the variation of the settling dust sample. A true sample, simulating that breathed by the worker should be collected by some suction device which will collect the dust from the atmosphere in the "breathing zone" of the subject.

The second factor is determined by microscopic measurement of an alcoholic suspension of the atmospheric dust. This sample is usually collected by drawing the air through a calibrated orifice through a dust-free alcoholic solution and impinging the dust momentarily on the bottom of the sample tube. The dust particles are wetted and thereby trapped in the solution. An aliquot of the dust suspension is allowed to settle in a glass counting cell and the size and number of particles determined by microscopic examination. Knowing the ratio of the aliquot to the volume of air sampled the number of particles per cubic foot of air may be determined.

The third factor is the one which is not given sufficient emphasis in Industrial Hygiene studies. It requires a time study of the job performed by a particular worker or group of workers and its correlation with the dust concentration, composition, and particle size.

## CONCLUSIONS RELATIVE TO SILICA DUST AND GAS EXPOSURE

A widely circulated statement among management as well as workers is that one builds up a partial tolerance to a "foreign" contaminate or noxious gas that is encountered in ones daily life. There is little from a medical standpoint upon which to base such a theory. For example in more than one local foundry in which dust, high in free silica is an industrial hazard, the management makes the statement that their working conditions are not hazardous to the health, as they have employees who have been on the job as much as 15 or 20 years without having a day of illness. The average worker accepts this statement as true, possibly because of its repetition from different sources. The sickness records of these plants do not bear out this fallacy, as the ratio of time loss and deaths in this type of work compared with an occupation having little dust exposure is fairly high. As one worker so aptly put it, "a strong, healthy man gains weight on the job, but not many men that lay off from sickness come back". This may be a rather biased statement, but it is food for thought.

In regard to exposures to sublethal concentrations of irritant gases the distinguishing feature of the poisoning is a catarrhal inflammation of the upper respiratory tract. On continuous exposure the sharp cough present in the beginning of the inflammation becomes less marked due to a tenacious mucous that develops over the surface of the upper respiratory tract, partially shielding it from the action of the gas. Due to a partial abolition of the respiratory reflexes little protection is given the deeper respiratory structure and the inflammation that results offers a breeding ground for bacterial infection. This condition is therefore detrimental to the general health and is more difficult to detect than an acute attack of gas poisoning. There is no truth in the statement that a tolerance may be built up for any irritant gas.

Some irritant gases are destroyed or neutralized in the respiratory tract and the products formed from the reaction does not cause any systemic poisoning after absorption. In the case of hydrogen sulfide and nitrous oxide these gases are neutralized to their salts, sodium sulfide and sodium nitrite, both which are systemic poisoning to the human system.

## ORGANIC CHEMICALS

Except in a small number of industries that manufacture organic chemicals the majority of the organic compounds that find use in industry are liquids. Industries have taken full advantage of the common property of most organic liquids in that they are good solvents or vehicles for many solids. At present the largest manufacturers or process users in Louisville are the distilleries, synthetic rubber plants, paint manufacturers and ordnance plants. Many factors govern the selection of a solvent for use in an industrial process. When there are a number of solvents whose properties make them suitable for the job the most economically priced one will be chosen. In recent years the toxicity of an industrial chemical has become a factor to be reckoned with in choosing an organic solvent since an incapacitated worker is a liability which must be written on the ledger along with the cost of the material. At present there are less than a hundred solvents widely used in industry. The toxicity and the permissible threshold limit of most of these organic liquids have been established. As this is a relatively new phase of physiological chemistry and medicine these limits are subject to frequent changes.

It has been stated that any substance taken in excess is a poison to the human body even though the substance be water. The harmful effects of solvents upon the human system varies from the least toxic, water, to such volatile liquids whose toxic properties make them useful as a war gas. The chemist has found that organic compounds may be grouped into families, the members of which have fairly similar chemical and physical properties. There is a similarity in the physiological effect within these groupings and this family grouping is used in discussing organic solvents in this paper. The solvents most widely used in industry may be grouped as follows:

GROUPING OF ORGANIC SOLVENTS (17)

| Chemical Family | Example of Members |
|---|---|
| 1. Petroleum distillate (aliphatic hydrocarbon) | Gasoline, benzine and naphtha |
| 2. Alcohols, Esters and Ketones | Methyl and ethyl alcohol and acetones |
| 3. Halogenated Hydrocarbons | Carbon tetrachloride and trichlorethylene |
| 4. Aromatic Hydrocarbon | Benzol (benzine), toluol and xylol |
| 5. Miscellaneous | Carbon disulfide |

A physiological property common to most of these compounds is that of inducing the symptoms of anesthesia when inhaled in sufficient quantities. Some solvents have only this physiological property while the majority of them have a systemic effect after absorption. Once absorbed it may change the blood picture and in many cases other organs such as the liver, brain and kidneys suffer the effects of an over-exposure.

Organic solvents may be divided into two general classes in considering their physiological effects on the body. In moderate doses they all produce anesthesia. The first group, of which ethyl alcohol is an example, when absorbed in sub-anesthetic concentrations does not cause chronic poisoning and organic changes in the body. When alcohol is ingested frequently and in large quantities, organic changes will develop in the nervous system and in the liver. These generalizations are true of this group of solvents. The other group exerts action beyond that of a simple anesthesia; they have a definite toxic effect. The hydrocarbons of the aromatic series and the halogenated hydrocarbons induce changes in the hemotopoietic system. After prolonged exposure to even sub-anesthetic concentrations, anemia, hemorrhages and loss of white blood cells may result. The halogen derivatives exert their toxic action on the visceral organs, particularly the liver and the heart.

PETROLEUM DISTILLATES

The first chemical family of solvents, the petroleum distillates, are those liquids resulting from the "cracking" or distillation of crude oil. The most common of these are naphtha (boiling point 65 to 120 centigrade), benzine (boiling point 110 to 150 centigrade) and gasoline (boiling point 90% below 200 centigrade). These solvents, being rather low in cost, have found wide application in industry. Naphtha is used in dry cleaning and sometimes gasoline and benzine are also used. Benzine has found increasing importance as a substitute for turpentine in paints. The use of gasoline is well known. Those that usually suffer from chronic exposure to its vapors are men that work in confined places where this liquid hydrocarbon is exposed to the air, as in cleaning tank cars, around storage tanks and pumping machinery used in transporting the liquid.

The striking feature of acute gasoline poisoning and, in general, as is characteristic of the homologs of this series, is the severe muscular convulsions occurring during stages of excitement. In some cases the muscular movements are as in an epileptic convulsion (13). With vapors of this type there is only a narrow margin between the concentration which produces anesthesia and that which causes death. Chronic poisoning by members of this alipathic series is probably common but it is not easy to diagnose because they do not produce characteristic symptoms. There is sometimes mild intoxication of the central nervous system, others report cramps in the abdominal region or nausea and dizziness (13). Exposure to vapors of this homolog series is quite common. The majority of the instances observed were of short duration and any after effects that may have occurred from such exposures were usually attributed to some cause other than inhalation of hydrocarbon vapors. Such exposures are found in the printing industry where type and ink rolls are cleaned with waste saturated with such a volatile solvent. Workers in occupations that require handling grease and oils as in machine shops, garages, filling stations, etc., employ these solvents rather freely in cleaning greases from their hands at the close of the day's work. Few workers are aware of the inherent dangers that may result from this practice. As has already been stated, there is an established permissible threshold limit on atmospheric concentrations for most chemicals used in industry. In a workroom containing less than this amount a normal person may work without ill effects. For gasoline the threshold limit has been set between 1000 and 1500 parts of vapor per million parts of air. Concentrations of 20,000 - 30,000 parts per million is fatal after a short exposure. The vapors of these hydrocarbons have a low solubility in water and in the blood. Due to this fact they are rapidly eliminated from the body when inhalation is discontinued.

## ALCOHOLS, ESTERS AND KETONES

The second group consists of the alcohols, esters and ketones. The members of the alcohol family find wide use industrially and in our everyday life. Ethyl alcohol is often consumed as a beverage in one form or another. The effect on the human system is about the same whether the vapors are inhaled or the liquid taken into the digestive tract. In the latter case the concentration reaches higher limits in the blood and the effects are more pronounced. If all the other factors are equal the pharmacological activity increases for each ascending member of an organic family, but the rule is tempered by the other physical and chemical properties of the individual member of the series. For example, in the alcohol family methyl alcohol is toxic to the human system because of its higher solubility and its essentially non-reactive character resulting in a cumulative action. The alcohol is slowly oxidized to formic acid which produces a degeneration of the ganglion cells of the retina and swelling of the optic nerves. In toxic exposures blindness will develop in 12 to 24 hours. The effects of ethyl alcohol should be more severe because of its higher molecular weight. The initial effects bear out this statement but this alcohol is readily split into carbon dioxide and water with the liberation of heat. Alcohols above ethyl, such as butyl, propyl, amyl etc., have their pharmacological activity modified or reduced because of their decreasing solubility and volatility.

Methyl alcohol is widely used as a solvent for lacquers, stains and as a denaturant for ethyl alcohol. Recently synthetic methenol has been placed on the market as an anti-freeze. The permissible threshold limits of methyl alcohol is 100 PPM. Since 1906 ethyl alcohol has gradually replaced methenol as the industrial alcohol. It was in 1906 that a measure was passed providing for revenue-free denatured grain alcohol. Alice Hamilton states that " — it (methyl alcohol) has done more damage in the United States than in all of the civilized countries put together (13)". The concentration of ethyl alcohol vapor considered safe for exposures of an eight hour working day is set at 250 PPM. This concentration will not cause any systemic effects; however, this amount in the air is severely irritating to the eyes and the upper respiratory tract.

An ester to a chemist is similar to an inorganic salt, being a combination of an alcohol and an organic acid with the loss of water. In the body the ester is broken down into its components and the toxicity may be determined by the concentration of these components.

The ketones are extensively used in industry as a solvent, extractive and intermediary in chemical synthesis; especially acetone, (dimethyl ketone). The permissible threshold limit of acetone has been variously stated at 200, 422, 1265 and 2110 PPM. This is due to the fact that little is known as to its fate in the body. Below concentrations which act as an anesthetic, there appears to be no organic injury to the body. The fact that toxicity increases as the homologous series rises, or as molecular weight increases, applies to the ketones and it is modified or reduced to a certain extent by the lowering solubility of the vapor in the blood as the series is ascended.

HALOGENATED HYDROCARBON

The next group to be considered, the halogenated hydrocarbons, is the most toxic and this group finds rather wide application in industry. Their effect is more destructive to the brain, liver and nervous system than any other one group even when the exposure is in relatively low concentrations. An important fact is the occurrence of wide individual differences in susceptibility to the toxic effects of some of these solvents. The concentrations which, on prolonged exposure, may produce chronic toxic effects vary widely between different individuals and are correspondingly difficult to establish. The concentration which will cause deep anesthesia and death for all individuals falls within narrow limits and can be readily established.

Industrial exposures to organic solvent vapors are usually in relatively low concentrations. It is usually due to some accidental cause that a worker is exposed to high concentrations of an organic liquid or vapor. These exposures are usually of short duration, terminated by death or removal of the unconscious victim.

Most every member of the halogenated hydrocarbon family will produce chronic effects upon animals and humans in prolonged and repeated exposure to concentrations which will not produce anesthesia. Here again the solubility of the solvent in the blood determines to a large degree the extent of the damage to the various organs of the body. Many of the halogenated hydrocarbons are in daily use in our homes and industries. Methyl chloride in refrigerators; trichloroethylene and tetrachloroethylene as industrial degreasers; chloroform and carbon tetrachloride as dry cleaners. Carbon tetrachloride is also used in certain types of fire extinguishers. These are a few of the well known and widely used solvents in this series. The estimated permissible concentration for prolonged exposure varies from 1.5 PPM for tetrachloroethylene and 32 to 100 PPM for carbon tetrachloride; to around 2,000 PPM for ethyl chloride. The best control measures for this type of solvent is ample exhaust ventilation at the source of the solvent. If this method of control causes a high solvent loss the process should be enclosed and refrigeration used to reduce solvent and vapor loss.

## AROMATIC HYDROCARBONS

The fourth group is comprised of the aromatic hydrocarbons. These are usually manufactured from the destructive distillation of coal and are, therefore, by-products of the illuminating gas and coke industries.

The principal constituents that we are concerned with are benzol, xylene, and toluene. Benzol is used in the blending of motor fuels, manufacture of paints, and as a general solvent. If the ventilation is inadequate the repeated inhalation of benzol vapors may lead to chronic poisoning. In concentrations too low to produce any immediate intoxication there may be subacute and chronic poisoning directed particularly against the hemotopoietic system. The maximum concentrations suggested as permissible for daily exposure to benzol vapors range from 31 to 75 or 100 PPM. The limits set for benzol may be applied equally well to toluene and xylene although the body damage due to high exposures are not exactly the same.

CARBON DISULPHIDE

Carbon disulphide is considered alone, due to the fact that it is one of the few liquids of its family which has found industrial use. It is less widely used now than formerly because of its odor, high toxicity and the fact that substitutes have been found to replace it. The permissible threshold limits that have been suggested range from 3 to 5 and even 20 parts of vapor per million parts of air. In chronic poisoning by carbon disulphide the chief damage is to the nervous system. Brief intoxication is usually unrecognized by the man effected but, this condition may add greatly to the possibility of industrial accidents.

## EXPLOSIVE MIXTURES

The essential characteristics of a vapor, gas, or dust explosion are the production of pressure and the rapid self-propagation of flame. The degree of inflammability of a material is indicated by its flash point; the lowest temperature at which a substance will ignite when it is sufficiently dispersed in the air to form an explosive mixture (34).

The ignition point is the temperature at which this dispersed matter - air mixture will, under favorable conditions, ignite spontaneously (27). It is also the lowest temperature at which there is more heat generated than is lost and therefore combustion becomes self-propellent. Beyond the lower and upper concentrations for the explosive range the matter - air mixture is no longer inflammable (10).

## ORGANIC SOLVENT VAPORS EXPLOSIONS

The flash point of the vapors of a liquid or of a mixture of liquids may be raised by replacing the low boiling liquid in part or wholly with non-inflammable or higher boiling liquids. Some of the chemical and physical properties which influence ignition temperatures are high calorific values, activity of valance forces and ease of chemical reaction. It has been observed that the simplicity of the molecular structure is associated with high ignition.

TABLE IX

EXPLOSIVE PROPERTIES OF SOLVENT VAPORS (27) (21)

| Solvent | Flash Point ° C. | Explosive Range Percent by Volume Low | High |
|---|---|---|---|
| Ether | -40 | 1.25 | 10.0 |
| Gasoline | - | 1.4 | 6.0 |
| Acetone | -20 | 2.5 | 12.8 |
| Methanol | 12 | 5.5 | 21.0 |
| Ethyl Alcohol | 13 | 4.0 | 14.0 |
| Ethyl Acetate | 3 | 2.25 | 11.0 |
| Isopropyl Alcohol | 12 | 2.5 | - |
| Isopropyl Acetate | 5 | 2.0 | - |
| Turpentine | - | 0.8 | - |
| Benzene 90% | -12 | 1.5 | 9.5 |
| Toluene | 8 | 1.3 | 7.0 |

Note: All work carried out at 25° C. and prevailing atmospheric pressure.

GASES EXPLOSIONS

Although the use of gases in industry is limited there are at present many processes that employ or produce gases of various types during their operation. The following list gives the limits of inflammability of a few of common ones.

TABLE X

LIMITS OF INFLAMMABILITY OF GASES (6) (21)

| Gas | Limits in Air Low | High |
|---|---|---|
| Hydrogen | 4.1% | 74.2% |
| Ammonia | 16.0% | 27.0% |
| Hydrogen Sulfide | 4.3% | 45.5% |
| Carbon Monoxide | 12.5% | 74.0% |
| Coal Gas | 6.0% | 33.0% |
| Illuminating Gas | 5 to 7% | 21 to 31% |

Due to the fact that gas molecules are rather small compared to the molecules found in solvent vapor or particles formed into dust, they have more freedom of movement and therefore are easily ignited. Gas mixtures have been known to explode by the heat generated from the catalytic action of a metal surface in contact with the gas or by photochemical reaction between two gases such as sulfur dioxide and hydrogen sulfide. The presence of an oxidizable oil in contact with oxygen, as on the valve of an oxygen cylinder, will cause a reaction forceful enough to rupture the cylinder.

DUST EXPLOSIONS

When any substance burns in air, the rate of combustion depends upon the surface area that is exposed to the air. The rate of combustion of wood shavings is many times greater than that of a block of wood and finely divided wood dust suspended in air will, upon ignition, burn with explosive violence.

CHART XI

EXPLOSIVE PROPERTIES OF DUST (10)

| Dust | 200 Mesh Screen | Relative Flammability #Per Sq. In. | Lower Explosive Limits Milligrams Per Liter of Air Glower | Arc | Induction Spark | Ignition Temp. |
|---|---|---|---|---|---|---|
| Corn Starch | 100% | 10.3 | 7 | 13.7 | 13.7 | 640°C. |
| Corn Elevator | 89% | 10.3 | 10.3 | 12.2 | 13.7 | 625°C. |
| Wheat Elevator | 89% | 10.3 | 10.3 | 12.2 | No "good-propogation" | 700°C. |
| Sulphur | 83% | 13.7 | 7.0 | 10.2 | 13.7 | 280°C. |
| Saw Dust | - | - | - | - | - | 635°C. |
| Sugar | 83% | 17.2 | 10.3 | 11.4 | 34.4 | 650°C. |
| Aluminum | 99% | 7.0 | 7.0 | 13.4 | 13.7 | 925°C. |
| Pittsburg Coal | 64% | 24.1 | 17.2 | 8.7 | No ignition | 900°C. |

The thermal properties inherent in the dust affects the lower explosive limit. Low temperatures of ignition and high heat of combustion influences the lower explosive limits of a dust. The specific heat or heat of absorption plays a definite part in the lower explosive limits. The chemical composition of cereal dust explains the variation in the lower explosive limits of these substances. Corn and wheat have a higher percentage of ash, cellulose and moisture than of starch. The pressure rises with the increase in concentration and is probably directly proportional to the concentration of the dust in the air. Regardless of the weight of dust suspended, coal and sulphur generally produce the lowest pressure upon explosion; sugar and elevator corn and wheat dust produce an intermediate amount and aluminum and starch dust produce the greatest pressure.

FIELD EXPERIENCE - INTRODUCTION

At present an Industrial Hygiene Bureau, whether sponsored by an insurance company, industry or the government consists of at least one medical doctor, experienced in industrial or public health medicine; a chemist; and an engineer. There should also be an office staff of secretary and clerk and if possible an industrial nurse.

In the future the services of an Industrial Hygiene Department may be considered as essential to good industrial operation as insurance services are today.

Government Industrial Hygiene Bureaus now function in a manner similar to other public health agencies. Industrial Hygiene services are made on a voluntary basis. Usually a spot coverage is made to determine the extent of occupational industrial health exposures in the area to be served. These are preliminary surveys and are actually visual inspections of the plant operations with emphasis placed on potential health hazards. A program of this nature will usually cover approximately ten percent of the industrial plants and the information obtained is used to set up a comprehensive industrial hygiene program. This type of program covers the medical, engineering and chemical study and evaluation of the potential health hazards of these industries. A complete chemical laboratory and the engineering equipment necessary to detect, analyze and measure these potential health hazards must be available. As this type of work is new and specialized, an extensive library is needed in order to answer the many questions that this type of work will evolve.

The I. H. engineer who serves as contact man for the bureau with industry must not only have at his finger tips health information, he must also secure the cooperation of the management, the union and the workers to insure a successful program. Very often he serves industry by informing them of additional services other bureaus of the health department can give them.

## STUDIES OF ATMOSPHERIC DUST, SMOKE AND FUMES IN THE LOUISVILLE AREA

As was stated above, Industrial Hygiene in the broadest sense of the word is public health principles applied to the welfare of our own industrial workers. Although it is beyond the scope of this paper to discuss all of these various ramifications of Industrial Hygiene, one other phase of this field should be mentioned. It is the effect of the atmospheric contaminants dispersed by numerous industrial processes upon the health of the worker who must breathe this air. Many of these workers also have their homes located in these areas of smoke and dust.

In 1940 Louisville was rated as having the third heaviest polluted atmosphere in the United States (29). Besides particulate matter such as soot and fly ash, in some sections there is present in the air "carbide plant dust" and also a certain amount of vapors and gases which are obnoxious.

The majority of the coal soot and fly ash results from incomplete combustion of soft coal. The Louisville and Nashville South Louisville Railroad Shops have recently completed satisfactory tests on a simple device that will eliminate all but a very minute percentage of the coal smoke from coal fired steam boilers. Battelle Memorial Institute's Fuel Division for the Bituminous Coal Research, Incorporated has developed a smokeless stove that may be used in the average home. Although these two developments are improvements that will eliminate a large percentage of foreign matter from the air the public will no doubt be slow to make the changes from the old type to the new. The removal of extraneous matter of this nature from the outside atmosphere is as much the responsibility of the householder as it is of the industrial plant.

Due to the heavy atmosphere throughout the Ohio Valley there may be found along with the smoke and dust many gases that tend to hang at low levels until there is a rise in the barometer pressure or a strong wind to take them away. Few complaints are ever made of the carbon monoxide or sulfur dioxide that is rather heavily dispersed in the air. Carbon monoxide, even in the low concentration which often occurs on the downtown streets, produces headaches for those who must breathe this air for a prolonged period of time. The so called rusting of exposed metal is not only oxidation due to oxygen and moisture but corrosion by sulfurous acid (formed from sulfur dioxide generated by the burning of soft coal). From this it may be readily understood what action these same acid gases have on our lungs, clothing, lead paints, etc. This is illustrated by the following incident.

During the winter of 1943 - 1944 in a small town located in the soft coal area of Kentucky many complaints were made relative to houses that had been freshly painted with lead paint the preceding summer. These houses developed metallic brown and black spots and in some cases severe chalking was noted. The winter had been foggy and damp and many people had complained of the sulfur taste of the air. A chemical analysis of some of the affected painted surfaces showed a higher percentage of sulfur than that normally found in paints of this type. The first heavy rains of spring removed most of these discolorations from the exposed surfaces. These discolorations were due to the sulfurous acid found in the air formed from the sulfur dioxide of the coal smoke combining with the moisture of the air which reacted with the lead of the paint. It was soluble enough to wash off during a heavy rain.

The southern and western sections of Jefferson County have suffered from dense clouds of carbide dust which comes from one of the war plants in that section. This dust is mostly lime "fines" which is one of the components of the charge used in their electric furnaces in the production of calcium carbide. During normal times pebble lime would be used with lump coke in charging these furnaces but as lime in this form has many more critical uses, this particular plant was forced to use a low grade of lime which is a combination of pebble and "fines". The furnaces are hand fired and to date there is no effective installation of a dust collecting system that will remove the dust before it is vented up the stacks. There are numerous dust collectors which would eliminate a large percentage of this industrial dust which is now permitted to cover the surrounding neighborhood. The public has given the carbide dust an odor which it does not have since it is mainly the oxide, hydroxide and carbonate of calcium mixed with some coke dust.

Other war industries in the "rubber town" area process many volatile liquids and some gases. Each plant has a safety vent located 75 to 100 feet in the air at which point excess flammable vapors and gases are burned. Although these vent lines have check valves to prevent flash backs in the line if the pressure drops, insurance rulings prohibit the burning of a pilot flame at the exit opening. Under these conditions there were times when odoriferous discharges were vented into the atmosphere without being burned. Winds carried both the carbide dust and these vented vapors and gases over the west-end of the city and so well mixed the two that the public opinion was that they were from a common source. Numerous atmospheric samples as well as sewer gas samples were taken in this area in order to trace the odors to their source. Even though the results of the analysis proved nothing of value the extensive investigation received so much publicity that the trouble was corrected. The plant or plants that were responsible for the odors took the necessary precaution of burning the escaping gases.

## INDUSTRIAL HAZARDS DUE TO CARBON MONOXIDE IN THE LOUISVILLE AREA

Although carbon monoxide is not the most toxic of gases, due to its lack of a prominent odor, it is one of the most treacherous of the gases and is one of the gases that few of us at one time or another have not been exposed to.

Wherever there is incomplete combustion due to lack of sufficient air there is present definite amounts of carbon monoxide. A poorly regulated air to gasoline mixtures in an internal combustion engine will dissipate exhaust gases containing up to 7% carbon monoxide. Many heavy industries use gasoline powered portable hoist and tow trucks to facilitate the stacking and moving of material within buildings. Only with regular maintenance of carburetor adjustment will the working atmosphere within these factories be kept below the maximum threshold limit for carbon monoxide of 100 parts per million.

Present day industry has replaced the blacksmith's forge with heat treated furnaces; some large enough to handle a continuous line of full size forgings. The majority of these furnaces are oil or gas fired and those of modern design have a semi-closed system of gas circulation into which is injected the heating flames. The system recirculates the gases over the flames and material under treatment until the gases are burned, usually to carbon dioxide and the maximum amount of heat is removed from the heating gas. As with internal combustion engines, only under rigid control is this process without hazard of carbon monoxide being vented into the working area. Up until recently better than 80% of these furnaces were not provided with exhaust gas vents to the outside. It was only after some near fatalities from carbon monoxide poisoning that steps were taken to remove this heat treated furnace spent gas to the outside, thus getting it away from the breathing zone of the workers.

Improperly vented coal or coke salamanders are potential sources of poisoning from carbon monoxide. Few cases are attributed to this type of heating equipment because they are usually used in the open or in buildings that have high ceilings and in which the sky-light ventilation is open in order to allow the escape of smoke and steam, as in the case of most foundries. Workers using salamanders in confined places are not as fortunate. In such working areas as are found in ship holds where this form of heat is resorted to, it has been observed that workers will leave their work to go "topside" for a "breather" with the complaint that their head feels tight, one of the first warning signs of the presence of carbon monoxide in the air. Hot air blowers from the upper deck eliminated this form of work stoppage.

The improper installation of a vent pipe on an auxiliary heating stove (with a wind from the east) resulted in one of our war plants closing down for three days.

## INDUSTRIAL CARBON MONOXIDE POISONING - PLANT Y

An instance of carbon monoxide poisoning occurred during the working hours of the so called "graveyard shift", the time from midnight to eight o'clock, in a workroom of a plant making small airplane parts. This particular workroom was on the second floor and it opened on three sides. There were 35 women and 3 men working at shaping stamped aluminum airplane parts by hand. At about three o'clock some of the women workers complained of dizziness. They had just returned from their lunch period, consequently the food which they had just eaten was the suspected cause of the discomfort. Later other women had the same feeling. Since the majority of the workers had brought their lunches from home the question of food poisoning was soon ruled out. By seven o'clock so many of the workers were affected that doctors were called in and ambulances were needed to remove the more severe cases. At the same time the Bureau of Industrial Hygiene was notified. By eight o'clock the situation was one of utter confusion. About eight workers were affected and those who were unconscious or semi-conscious had been removed to the hospital. By one o'clock sixteen women were under treatment at three local hospitals. When the ambulances were called word was sent to the City Police and the FBI that women were being overcome in this war plant from some unnamed cause. The presence of the police and the psychological effect of the uncertainty of the situation produced hysteria among other workers who had to be hospitalized.

The following were the suggested causes of the sudden epidemic of fainting:

1. Food poisoning.
2. Doped coffee - that was brewed at the plant.
3. Sabotage - by releasing a bomb of gas or by doping the drinking water.
4. An act by some who held a grudge against the company.
5. Poor ventilation of workroom.

After three days of intensive investigating of every possible clew the source of the trouble was located in a poorly designed vent pipe attached to an auxiliary heating stove which burned wood and trash. The vent pipe to the stove ran horizontally out of a window. The wind on the night of the instance just described was blowing from the east and had blown into the vent pipe and caused poor combustion in the stove thus liberating large amounts of carbon monoxide into the air of this room. To prove this theory these conditions were duplicated and a Mine Safety Appliance Company's carbon monoxide indicator showed around 500 PPM of carbon monoxide being emitted from the vent pipe into the room. Blood tests of the victims along with their general reactions bore out the fact that the majority of the women suffered from carbon monoxide poisoning while the remainder were affected by mass hysteria.

During the investigation another possible source of carbon monoxide poisoning was discovered before anyone was affected. A heat-treat bath of nitrate salts used in the hardening process of aluminum was gas heated and the sleeve on the vents had worked loose. Tests at the break in the vent pipe showed over 1500 PPM carbon monoxide escaping and from 180 to 500 PPM carbon monoxide in the other parts of the room. This bath was attended intermittently and due to the heat from the bath the windows were kept open while it was in operation.

The above instance of faulty venting and poor combustion cannot be classed as an accident although the conditions that resulted in the carbon monoxide poisoning of these women would rarely ever occur again according to the laws of chance. If proper precaution had been taken in installing the vent pipe to the wood stove the above accident would never have occurred. As was stated earlier in this paper carbon monoxide is not a naturally occurring gas but very often we are either consciously or unconsciously exposed to it. Operating automobiles improperly vented or improperly adjusted gas stove are every day sources of this dangerous gas.

## INDUSTRIAL USE OF CHLORINE IN THE LOUISVILLE AREA

Chlorine finds use in industrial processes where advantage may be taken of its highly reactive state. In Jefferson County there is one of the largest hydrochloric acid plants in the country. Large quantities of chlorine are produced in Hooker Cells. Every modern safety measure is taken to protect the health of the operators. The only time there is a heavy concentration of chlorine in the working area is after a mechanical failure of equipment. On these rare occasions maintenance men equipped with Bureau of Mines approved respirators enter the area and make the necessary repairs.

Liquid Chlorine is used to flux molten aluminum; it assists in removing certain undesirable impurities. Until proper protective masks were provided for the workers this operation was not without hazards. Chlorine gas in the presence of moisture is very corrosive to metal fittings and is also detrimental to the connecting rubber tubing. Many times workers had to leave their jobs to avoid being gased because of mechanical failures at these points.

The value from a safety and health standpoint of checking all hose connections and fittings before using such equipment has convinced the management that this is a wise measure to take in order to protect the worker's health. Bureau of Mines approved gas masks are within arms reach of the operators at all times in case the equipment should fail.

## INDUSTRIAL EXPOSURE IN THE LOUISVILLE AREA TO SILICA DUST - PLANT X

Besides a number of foundries producing gray iron casting who have a potential silica dust exposure there is an industry in Louisville that handles diatomaceous earth, which like sand is high in free silica. This industry manufactures a highly refractive brick by the unique process of fusing a clay-mineral mixture by means of electric furnaces to a molten state and pouring the material into molds formed of slabs of a baked mixture of sand, starch and oil. These slabs serve as a surface upon which the molten refractory is surface chilled to the point that it will hold its shape, the slabs disintegrate in the process. In order that the blocks may cool slowly they are covered with diatomaceous earth. After the block has cooled the diatomaceous earth is removed from around the block (the block and mold are held in a large iron box called a "can") and the block removed by hoist to be finished to certain specified dimensions.

There are many other materials handled in this industrial process. Some, analyzing only a trace of free silica, to quartz sand which contains about 97% free silica. The four materials highest in free silica are listed below. The other siliceous materials used have the greater portion of their silicon bound as silicate.

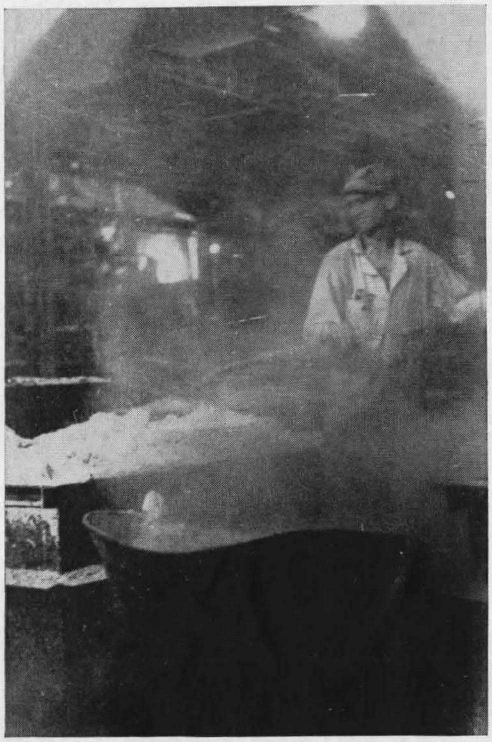
### CHEMICAL-PETROGRAPHIC ANALYSIS OF PLANT X (11)

| | Free Silica |
|---|---|
| Diatomaceous Earth | 74-76% |
| Armstrong Quartz | 77.5% |
| Johns Mansville Quartz | 73.0% |
| Quartz Sand | 96-98% |

As is true of the majority of the industries confronted with a dust problem the harmful effect is exercised by dust of mixed composition, but the criteria of pneumoconiosis - producing particulate contaminant is its free silica content of those particles below 10 micron in size.

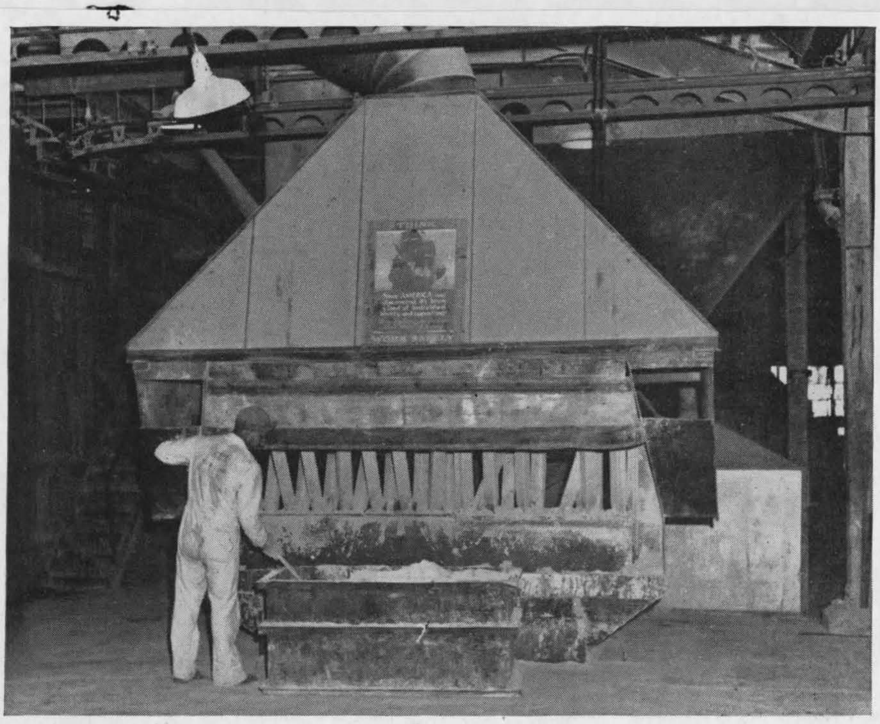
Using the above survey study as a typical example, the difficulties encountered in evaluating and industrial hazard can be illustrated. The atmosphere dust samples were obtained with a midget impinger: a portable suction pump, and sampling tube containing an alcoholic solution. The time required to obtain a sample was from one to five minutes and was governed by the concentration of dust estimated to be in the air and the length of time necessary to perform the job under study. Compared to an eight hour work day this is but a momentary measurement of the dust concentration breathed by the worker. At present, with the instruments now developed it is not practical to measure the dust concentration in a continuous manner. In this industry working condition of an individual worker varies almost continually and is controlled to a large extent by the time schedule of the furnace pourings. From this it is readily seen that it is impossible to obtain a continuous picture of the exposure of a worker to silica dust. Weighted spot test is the present method of evaluating a health hazard.

CHART - XII



**Before Installation of Control Measures**

1942



**After Installation of Control Measures**

1944

METHOD OF CONTROLLING SILICA DUST EXPOSURE IN "CAN" CLEANING OPERATION AT PLANT "X"

EVALUATION OF CHEMICAL HAZARDS

As a large percentage of industrial chemical hazards are due to gases, vapors or dust dispersed in the breathing zone of the worker, samples of these atmospheric contaminates are usually trapped in "bubblers" or impinges tubes. In case of gases or vapor evacuated gas sampling tubes are sometimes used.

Methods of chemicals and physical analysis follow standard methods with the limiting factor that they must be selective and sensitive enough to detect and evaluate the minute quantities that have been set as the threshold limit for the substances in question.

The field measures made by the engineer are conducted with standard instruments with some modifications.

These physical and chemical means of measuring toxic substances will not be discussed in detail as many references to them will be found in the literature and Jacob's "Analytical Chemistry of Industrial Poisons, Hazards and Solvents (21)" has become a text in this type of work.

In this field there is a distinct need for more portability in the field equipment used by the engineer. Not only should the weight of the instrument be reduced for weight's sake, but unwieldy equipment is a distinct hazard when used in an industrial plant. Microchemical and spot test methods are a partial solution to this problem.

The most powerful tool an Industrial Hygiene Engineer can use to convince the proper party of the existing health hazard is the chemical analysis or the results from a physical testing instruments used to measure the atmospheric contaminate. These figures compared with the established threshold limits and a sound group of reasons to back up these figures usually convinced the most conservative business manager, of the necessity of protecting his worker's health with suitable exhaust ventilation, isolation of the hazard, or other protective devices.

## IMPROVEMENT IN INDUSTRIAL HEALTH PROTECTION IN LOUISVILLE IN THE LAST TEN YEARS

There are usually progressive leaders in any field of endeavor and so it is among the industrial establishments of Louisville. There are a number of plants that, since their founding, have held to high standards in regard to the employee's welfare and health. This program has usually been instigated by the management and carried on through the cooperation of the workers.

There is a small percentage of management that has more regard for their machinery than they do for the working conditions of their employees. This group is gradually becoming aware of the fact that a respected worker is a more productive worker.

In recent years and with greater impetuous since the war, the efforts of the unions and the educational program of Industrial Hygiene has improved the working environment within our industrial plants.

The results of the Industrial Hygiene program has been slow but progressive. The acceptance of a new program such as this by business men is usually slow, but as soon as this bureau had established itself more plants took advantage of its benefits until requests were made in large numbers for the service of the Industrial Hygiene Bureau of the Louisville-Jefferson County Health Department.

It would be impossible to make a blanket statement as to the improvement it has made toward a healthier working condition in the industrial plants of this area as each survey was an individual problem and with a limited staff each plant could not receive all the services some of them warranted. Such a program is dynamic and to reach perfection must cover all the plants and anticipate any hazards that may arise from changes made in the manufacturing processes of these plants. It can be stated that a comparison of general working conditions from a health standpoint ten years ago with those that exist today will show that an Industrial Hygiene Bureau in this area has been a definite asset to the community.

CONCLUSION

It is indeed more the rule than the exception that industrial chemical hazards are usually a by-product or end-product of a manufacturing process. If a relative toxic substance is handled or processed the necessary precautions in guarding the health of the employees are taken, otherwise the workers would suffer injury or death and due to its hazardous nature the process would have to be abandoned.

In Industrial Hygiene Engineering work as much time is spent on a chemical hazard that may effect only a few workers as an exposure that may evolve hundreds of workers. There were many studies made on such small operations, as pickling tanks made from barrel halves and degreasing tanks fashioned from an enameled bath tub. Each may have endangered the health of only one or two workers, but their health is just as important to them and the City-County Health Department as an exposure which may affect the health and lives of hundreds of workers.

The typical examples of industrial exposures to chemical hazards (page 54 to 67) illustrate the type of situations encountered by an industrial hygiene engineer. These have been publicized by the press and are therefore available for use. The other actual or potential industrial health hazards that were found in Jefferson County cannot be published because of the confidential nature of the Bureau's service. They are discussed only as generalities in this paper.

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